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Ulku Yaylacicegi

*University of North Carolina Wilmington, Wilmington, NC, United States., yaylacicegiu@uncw.edu*

Stacy Mitchell

*University of North Carolina Wilmington, Wilmington, NC, United States., mitchells@uncw.edu*

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# Differential Impacts of Four Types of EHR Implementation on Small, Medium, and Large Hospitals

**Stacy Mitchell**

University of North Carolina, Wilmington  
Department of Information Systems and  
Operations Management  
Wilmington, NC 28403, USA  
[mitchells@uncw.edu](mailto:mitchells@uncw.edu)  
910-962-2162

**Ulku Yaylacicegi**

University of North Carolina, Wilmington  
Department of Information Systems and  
Operations Management  
Wilmington, NC 28403, USA  
[yaylacicegi@uncw.edu](mailto:yaylacicegi@uncw.edu)  
910-962-3901

## Abstract

Hospitals invest in information technology to lower costs and to improve quality of care. However, it is unclear whether these expectations are being met. This study explores EHRs in a hospital environment and investigates their relationship to quality of care and patient safety based on the hospital size. In order to advance research and assimilate knowledge in this area, EHRs are categorized into four functional groups: patient information data, results management, order entry and decision support. This new knowledge will provide a better understanding of the relationship between EHRs and operational outcomes by showing the impact of various EHR functions on patient safety and quality of care. The analyses show that large and medium hospitals implement more EHRs than small hospitals. EHR component analyses show more effects on small and large hospitals while medium hospitals analysis revealed no evidence of change.

**Keywords:** Electronic Health Records, Patient Safety, Quality of Care

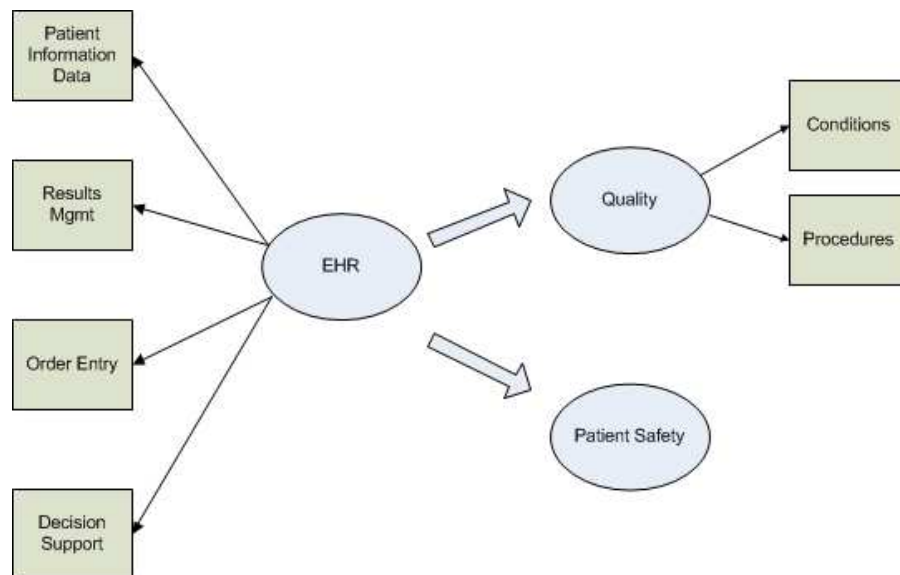
## INTRODUCTION

American health care has continued to be criticized as fragmented, expensive, unsafe, and unfair over the past few years [1]. Health information technologies (HITs) have emerged as one remedy promising reductions in waste, gains in communication, improvements in quality and new accountabilities through automated performance measurement [2]. Recent studies show that benefits from these information technologies have been recognized [3, 4]. One such HIT is the electronic health record (EHR). Electronic health records are defined as a longitudinal collection of electronic health information about individual patients and populations. It is ‘a mechanism for integrating health care information currently collected in both paper and electronic medical records (EMR) for the purpose of improving quality of care’[5]. While EHRs have been shown to have the potential to improve the efficiency and effectiveness of health care providers [6, 7], U.S. health care providers have been slow to adopt them [8, 9]. President Bush declared in a January 2005 speech at the National Institutes of Health in Bethesda, Maryland that, “We’ve got 21st century medical practices, but (a) 19th century paperwork system.” Nearly 7 years later, the substance of the President’s statement still holds true. However, hospitals investing in the safety of their patients and care practices of their clinicians are working to change that through the implementation of Electronic Health Records [10]. Even more recently, President Barak Obama has made healthcare a centerpiece of his presidency and in 2009 unveiled \$1.2 billion in federal grants for electronic health records systems [11]. With such support and a policy in place that calls for universal EHR adoption by 2014, it is imperative to have a solid understanding of the impact that EHRs have on operational outcomes, such as; quality of care and patient safety.

Due to limited scholarly literature on the impact of differential EHR implementation on quality of care and patient safety, researchers and practitioners lack the necessary resources required to aid in the educated decision making

process of technology selection. The study of Bourgeois [12] showed evidence of improved quality of care and patient safety following EHR implementation. However, there is overwhelming evidence of the variance in possession, usage and utilization of HIT investments in healthcare organizations of differing sizes [13-17]. There is currently an absence of empirical evidence showing EHRs overall and differential impact on quality performance and patient safety across small, medium, and large hospitals. This study aims to examine the economic returns of usage and utilization of costly HIT investments and inform healthcare administrators of the results to assist with decision making regarding EHR implementation based on hospital size. Finally, provisions for subsidies provided by government for capital investments can be influenced by the impact of EHR usage on healthcare quality.

This study will progress research by expanding EHR investigation to include operational outcomes of acute care hospitals (Figure 1) across varying institution size. Specifically, the inclusion of quality and patient safety metrics that have been developed and validated by the Agency for Healthcare Research and Quality (AHRQ) and utilized in previous healthcare research will broaden the scope of knowledge. These measures will allow us to answer the questions, “How do the effects of aggregate EHR implementation vary across hospital size?” and “How do the effects of differential EHR implementation vary across hospital size?” The partitioning of data and analyses of our model across hospital size (small, medium, and large) will provide a better understanding of the relationship between EHRs and operational outcomes by showing the impact of various EHR functions and let us address which EHR functions are most beneficial in each situation. This new knowledge will help provide guidance to hospital managers and practitioners in the selection of EHR components for implementation.



**Figure 1 Conceptual Model**

## LITERATURE

Current scholarly literature has given much attention to the potential improvements in quality of care that can be obtained by EHR implementation. Studies have predicted that EHR will help in the reduction of medication errors [18-20] and in the improvement of quality in health care services [13, 21]. However, current literature on EHRs is not easily generalized; with most studies limited to single site evaluations of academic hospitals with internally developed systems [6]. In contrast, most US hospitals purchase commercially developed EHRs. Few studies have been performed to determine the effects of EHRs on in-patient quality of care and patient safety in multi-hospital networks. Further, it has been noted that there are several factors influencing the decision of whether a hospital adopts an IT system, such as; hospital size, teaching status, ownership, and location [13, 14, 22-24]. Of these factors, hospital size has been a controversial topic. Some authors have found large hospitals to have more clinical IT systems than smaller hospitals [13]. While others did not find any (consistent) influence of hospital size on the prevalence of clinical IT systems [14, 15]. However, it is recognized that hospitals that differ in size are also likely to differ with respect to location, kind of patient admitted, services provided and other characteristics [17]. Additionally, research shows that larger shares of all hospitalizations occur in large hospitals. For example, in 2005, 23 percent of hospital admissions occurred in hospitals with 500 or more beds, compared to 4 percent in hospitals with fewer than 50 beds [16]. These statistics reinforce that hospitals of varying size do not experience the same

work flow. Therefore, analysis of performance should not occur collectively (as the majority of current literature reports), but rather hospitals should be grouped by patient density and performance investigated separately by size. This discussion leads to our hypotheses:

*H1: The usage of EHR will lead to improved patient safety and quality of care in large hospitals.*

*H2: The usage of EHR will lead to improved patient safety and quality of care in medium hospitals.*

*H3: The usage of EHR will lead to improved patient safety and quality of care in small hospitals.*

## CONSTRUCT DEVELOPMENT

### Electronic Health Records

Electronic Health Records (EHR) is operationalized in this study using data collected from the American Healthcare Association's annual survey. Hospitals were surveyed regarding the presence of an EHR and the implementation status of the EHR (fully or partially implemented). Further, EHRs were dissected into four categories: Patient-level information data, Results management, Order entry management, and Decision support. Hospitals Information pertaining to the implementation of each category of EHR was then assessed as fully implemented, partially implemented, or not implemented.

### Quality and Patient Safety

For purposes of this research the Agency for Healthcare Research and Quality (AHRQ) Inpatient Quality Indicators (IQIs) and Patient Safety Indicators (PSIs) were adopted to operationalize the constructs *Quality* and *Patient Safety*. The IQIs focus on the health care provided within an inpatient hospital setting and the mortality rates provided are a proxy measure of *Quality*. PSIs are a set of measures that can be used to screen for adverse events and complications that patients may experience as a result of exposure to the health care system. The PSIs provide a measure of the potentially preventable complication for patients who received their initial care and the complication of care within the same hospitalization. Provider-level indicators are included in this study and report only those cases where a secondary diagnosis code flags a potentially preventable complication. Scientific evidence for these indicators is based on reports in peer reviewed literature. Structured literature review and empirical analyses were used to establish validity of the indicators and details regarding the development process are presented in the publication "Refinement of the HCUP Quality Indicators" available at [www.qualityindicators.ahrq.gov](http://www.qualityindicators.ahrq.gov) [25].

Eleven mortality measures are utilized to examine quality of healthcare. These measures evaluate outcomes following procedures and for common medical conditions. The mortality indicators are divided into two quality constructs for analysis: procedures and conditions. All mortality measures are reported as part of this research, with the exception of carotid endarterectomy, hip fracture, and hip replacement because of the low volume of such procedures performed in our sample from the state of Texas. Data are not considered valid if a hospital treats fewer than 25 qualifying patients [26, 27]. The recognition of data measures with fewer than 25 cases as being potentially unreliable and invalid is consistent with the Centers for Medicare & Medicaid Services (CMS) recommendation for use of these data stating, "...that the number of cases is too small (fewer than 25) to reliably tell how well the hospital is performing" [28].

Eleven safety indicator rates that provide information on potential in-hospital complications and adverse events following surgeries and procedures are divided into two safety constructs: general safety and post-operative safety. Indicators that were coded as rare (may not have adequate statistical power for some providers), under-reported (conditions included in this indicator may not be systematically reported leading to an artificially low rate), or screened (leading to a higher rate in facilities that screen) were excluded from the model due to validity concerns raised by the AHRQ and possible skewing of the data [29]. Additionally, the four obstetrics indicators were not included in this study; it has been shown that the risk of obstetric trauma is significantly influenced by both patient and hospital characteristics and is not a good indicator of patient safety [30].

All employed IQI and PSI measures in this study, with the exception of Death in Low Mortality diagnostic related groups (DRGs), are risk-adjusted rates that reflect the age, sex, modified DRGs, and comorbidity distribution of data in the baseline file, rather than the distribution for each hospital. The use of risk-adjusted rates facilitates the ability

to generalize the data and puts each hospital “on an even playing field.” The observed rate for Death in Low Mortality DRGs is measured due to the risk-adjustment transforming all hospital rates to zero. Table 1 displays the comprised indicators for each construct.

Study Scale Items	Factor Loadings
<i><u>Mortality</u></i>	
Procedures:	
AAA Repair	0.595
CABG (Coronary Artery Bypass Graft mortality)	0.826
CRANI (Craniotomy mortality)	0.750
PTCA (Percutaneous Transluminal Coronary Angioplasty mortality)	0.792
Conditions:	
AMI (Acute Myocardial Infarction mortality)	0.843
AMI wo Trans (AMI with out transfer cases mortality)	0.853
CHF (Congestive Heart Failure mortality)	0.692
STROKE (Acute Stroke mortality)	0.571
<i><u>Patient Safety</u></i>	
PO_RESP (Post Operative Respiratory Failure)	0.652
PO_DVT (Post Operative Deep Veing Thrombosis)	0.693
PO_SEPS (Post Operative Sepsis)	0.616
PO_WND (Post Operative wound and dehiscence in abdominopelvic) patients)	0.570
PO_SEL (Selected Infections Due to Medical Care)	0.599
PO_IAT_PNEU (Iatrogenic pneumothorax)	0.575
PO_ULCER (Decubitus Ulcer)	0.685

**Table 1 Constructs and Factor Loadings**

## METHODS

The primary analysis of the relationship between EHR implementation, quality, and safety was performed using secondary data collected and compiled from three data sources. The American Hospital Association’s (AHA) annual hospital survey provided information pertaining to EHR implementation, type of EHR function employed, and physician usage of EHR. The DFWHC database supplied inpatient quality indicators (IQI) and patient safety indicators (PSI) that were developed by the Agency for Healthcare Research and Quality (AHRQ). Finally, the American Hospital Directory (AHD) provided key hospital characteristics and demographic data.

In order to combine datasets, the AHA survey data of 577 Texas hospitals was reviewed. Records with incomplete or missing data were removed and EHR information was gathered for the remaining 364 hospitals. Second, demographics, IQIs, and PSIs for the Texas hospitals were extracted from their appropriate databases. The hospitals from both databases were then relationally joined to the sample from AHA and a new sample dataset was formed. All hospital information, including names, IDs, and addresses, were evaluated to ensure accuracy in the merging of datasets. Any hospital not appearing in all three data files or who could not be confidently identified as matches were deleted from the sample. Upon completion of merging and cleaning of the datasets, the sample included 208 Texas acute care hospitals.

The AHA Annual Survey included a question that asked, “Does your hospital have an electronic health record?” Possible responses were: yes, fully implemented; yes, partially implemented; and no. In addition, a question regarding the type of functions of the EHR was asked, “Does your electronic health record include: 1) Patient-level health information and data (such as medications, orders, and clinical notes), 2) Results managements (such as results from laboratory tests, radiology studies, and other tests), 3) Order entry management (such as orders for laboratory tests, radiology studies, and other tests), and 4) Decision support (such as knowledge sources, drug alerts, reminders, and clinical guidelines and pathways). Each question had the following possible responses: yes, fully implemented; yes, partially implemented; and no. Therefore, we coded the EHR variable according to their implementation status with no responses receiving a zero, partial implementation receiving a one, and full implementation receiving a two. We considered blank responses as not using an EHR and therefore coded these as zero in the study analysis.

## Descriptive statistics

Classification trees found that 27% of the variation occurring in the data can be attributed to hospitals of varying size. Through partitioning using JMP 7.0 (visual discovery software from SAS) hospitals were grouped into small, medium, and large size based on general and specialty beds available. The groups were defined as small being all hospitals with less than 100 beds, medium consisting of hospitals with between 100 and 300 beds, and large hospitals categorized as having more than 300 beds. This classification coincides with current nursing literature [31-34]. Division of the dataset into groups by size resulted in 3 subsets of data representing small hospitals with a sample size of 93, medium hospitals with a sample size of 75, and large hospitals with 40 observations. Results from analyses indicate that a statistically significant difference exists in the amount of Decision Support ( $p < 0.000$ ), Order Entry ( $p < 0.000$ ), Patient Level ( $p < 0.000$ ), and Results Management ( $p < 0.000$ ) EHR components available for use between hospitals of different size. Tukey and Bonferroni post-hoc analyses disclosed that the statistically significant difference exists between large and small hospitals ( $p < 0.000$ ) and between small and medium hospitals ( $p < 0.001$ ). Both large and medium hospitals have a higher ratio of EHR components available for use than small hospitals. This supports theory that larger organizations have more funding available for information technologies and specifically electronic health records [12].

## Data Analysis

A composite score was generated utilizing factor scores and loadings by SPSS 18 software for all three constructs (patient safety, quality: procedures, and quality: conditions) for each hospital. The composite scores allowed comparison of the constructs across small, medium, and large hospitals.

In order to alleviate analysis restrictions due to small sample sizes, analysis of variance was utilized to investigate both the aggregate effect of electronic health records and the EHR component effects. Due to the fact that some hospitals have multiple EHR components implemented, the possibility of interactions had to be considered. In order to account for this interaction the analyses were conducted with the EHR components as covariates.

## Results by Hospital Size

Hospitals with fewer than 100 general and surgical beds comprised the category of small hospitals. Aggregate analysis of overall EHR implementation showed a statistically significant difference in composite scores for the constructs patient safety and quality: conditions. Further analyses encompassing EHR components revealed that patient-level data, order entry, and decision support significantly improve quality in care of patients after certain medical procedures. While no significant change existed in the construct quality: conditions, small hospitals did see highly significant changes in patient safety when order entry and decision support systems were in place and an increase in quality: procedures when patient-level data was utilized (Table 2).

Therefore, our results imply that patient safety and quality in procedures for small hospitals could be improved by implementing order entry and decision support components of electronic health records. It is not expected for quality conditions to improve as these generally are pre-existing conditions where patients have long-term health issues generally resulting in death. Further, small hospitals tend to be in more rural areas where there is only one hospital available to address many varying health issues and complications. Being the only hospital within a region's radius, smaller hospitals have access to patient records within one general repository. This allows caregivers access to pertinent information on patients that helps to decrease mortality rates due to prevention of drug interactions. Additionally, having access to all patient history and an order entry system enables the provider to better determine the necessary and precise tests that would circumvent any confusion and aid in the patient's diagnosis when time is of the essence.

Size	Large			Medium			Small		
	Patient Safety	Procedures	Conditions	Patient Safety	Procedures	Conditions	Patient Safety	Procedures	Conditions
Patient-Level Data	.157	.348	.142	.193	.356	.343	.101	.030*	.150
Results Mgmt.	.093	.308	.352	.209	.448	.464	.159	.387	.354
Order Entry	.008*	.018*	.495	.485	.224	.295	.000*	.016*	.474
Decision Support	.027*	.083	.130	.298	.354	.297	.016*	.028*	.474

Table 2 MANOVA Significance

Next, medium hospitals (between 100 and 300 beds) showed no statistical evidence that EHR implantation has any impact on patient safety or quality of care. Most medium sized hospitals are in more urban areas and are very limited in the healthcare services they offer compared to the larger hospitals. They are stand-alone entities, i.e. don't exchange medical records electronically with other health organizations. The lack of comprehensive medical records prevents them from utilizing EHRs effectively.

Finally, large hospitals with greater than 300 beds yielded a dataset of 40 observations. Results indicate that decision support and order entry have a significant impact on patient safety and quality: procedures. Further, we find that decision support significantly effects patient safety. Once again we find no significant relationships between EHR components and results management. Large hospitals are often in metropolitan areas where there are many branches sharing medical records electronically. Similar to small hospitals, large hospitals handle a multitude of patients with unpredictable health concerns. They also have direct access to comprehensive medical records that assist the providers with improved decision making. In addition, large hospitals have greater resources such as MRIs and CAT scans that help to develop a more comprehensive understanding of a patient's needs. On the other hand, large hospitals tend to see more difficult cases and have a much more diverse case mix than small and medium hospitals. One would expect that results management would also have a significant impact on patient safety and quality of care; however, larger hospitals are often the last resort for many patients with serious terminal health conditions and these cases lead to higher mortality rates.

## CONCLUSION

The investigation of the value of electronic health records is becoming increasingly important. In 2004, the former President Bush issued an executive order that encouraged the adoption of various forms of health IT. In the past U.S. Presidential campaign, nearly all candidates mentioned health IT in their campaign speeches and debates. And more recently, President Obama's economic stimulus plan was implemented with approximately \$20 billion earmarked for the introduction of IT into the healthcare system. Interestingly, while most studies suggest there is value in the adoption of these technologies the results are not entirely conclusive, suggesting one of two things: 1) there is too much error in the current state of research measurement, or 2) value is heterogeneously distributed among firms and results are highly contingent upon context. Our goal in this study was to take a highly focused approach to EHR-value by examining application-specific components and their influence on related outcomes.

This study advances research by looking at the mortality indicators for quality as divided into two separate constructs: surgical procedures and conditions. By dissecting the mortality indicators we are able to observe the

significant positive relationship between EHRs and surgical procedures that has previously been undistinguishable. The most beneficial aspect of this research comes from the analysis of our model across hospital size. Firm size is typically considered an important control variable in studies of organizational impacts of technology [35-37], because it is possible that larger hospitals might have systematically better performance due to the resources available to them [38]. Additionally, hospitals of varying size tend to see different types of patients with varying degrees of illnesses and complications. Larger hospitals tend to see more complex surgical situations and more difficult patient conditions [39]. For example, a small to medium size hospital is more likely to see a case of tonsillitis than one of malaria which would be deferred to a larger organization.

With the amount of money spent each year on IT, it is critical to understand what role these advancements play within the operational aspects of our healthcare system. The study presented provides a starting point into investigations of information technology in healthcare, specifically in the domain of electronic health records. The question was posed as to whether or not EHRs can facilitate an environment in which hospitals can provide higher quality of care and at the same time improve patient safety. The answer based on the research presented is yes; the use of EHRs has the potential to decrease mortality rates while significantly improving patient safety. These findings support that electronic health record systems are much more than record keeping devices. They include numerous features that have the potential to vastly improve health care outcomes. They provide physicians with preventive care reminders, allergy alerts, suggestions for diagnostic or treatment options, links to medical literature, computerized physician order entry, and data analysis tools that reduce medical errors and improve patient safety and quality of care.

The recent environment for health care organizations has focused attention on providing high quality of care at a containable cost. While the adoption of EHRs promises to improve clinical outcomes and increase patient safety, it is important to note that EHR systems are comprised of several functionalities that must be used in an integrated manner in order to realize their full potential [40]. As seen in this study, it is possible to partially adopt an EHR by using only selected functionalities of the system. Through rigorous analysis, this study shows how differing EHR functions impact hospitals of varying size and allows recommendations to these organizations on which technologies to invest in for their firm. From our research we can suggest to providers and policy makers that small and large hospitals that invest in EHRs (specifically, order entry, patient-level data and decision support) realize higher patient safety and greater quality of care in procedures.

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